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2020 DOE VEHICLE TECHNOLOGIES OFFICE ANNUAL MERIT REVIEW
JUNE 3, 2020

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

CHARGING INFRASTRUCTURE NEEDS FOR ELECTRIFICATION OF FREIGHT DELIVERY VEHICLES

VICTOR WALKER
Idaho National Laboratory (INL)

Alicia Birky, NREL
Amy Moore, ORNL

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY
BERKELEY LAB
INL Idaho National Laboratory
NREL NATIONAL RENEWABLE ENERGY LABORATORY
OAK RIDGE National Laboratory

OVERVIEW

Timeline

- Project start date: December 2018
- Project end date: December 2019
- Percent complete: 100%

Budget

- Total project funding: $350K
  - INL: $250K
  - NREL: $50K
  - ORNL: $50K

Barriers and Technical Targets

- Understanding methods to enable electrification of freight solutions.
- Challenge to identify the most important levers to improve the energy productivity of future integrated mobility systems
- Complexity of large-scale integrated transportation networks

Partners

- Idaho National Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory

RELEVANCE

Energy for movement of goods is a critical component of mobility

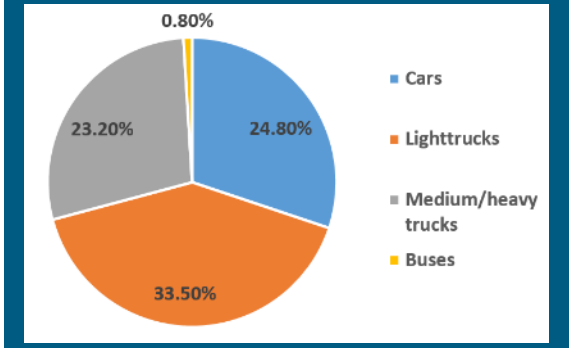
Impact:

- Trucks are by far the single most-used mode to move freight in the United States
- Electrification of freight trucks, particularly class 7-8, is a key to improving the energy efficiency of the national transportation system

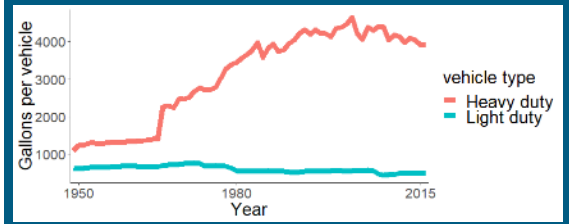
Objective:

- Study motor carrier industry to determine drivers for and inhibitors to electrification and explore options for charging infrastructure technology and deployment

Total mobility energy by vehicle type



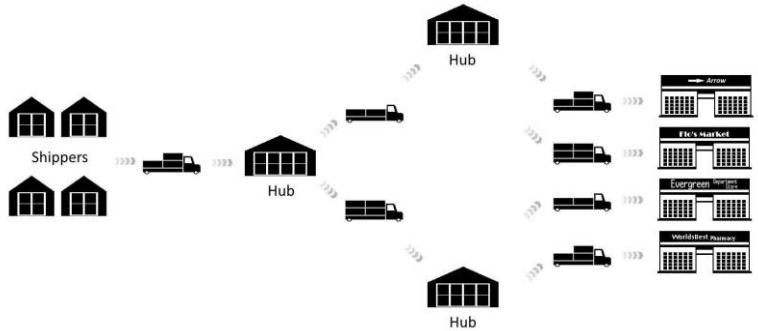
Growth of fuel consumed by vehicle type



APPROACH

Energy for movement of goods is a critical component of mobility

- Conduct industry segmentation and stakeholder analysis
- Estimate the performance of trucks and infrastructure
- Examine real-world data of freight movement
- Examine scenarios with potential charging solutions to examine impacts



APPROACH

Milestone Name/Description	End Date	Progress
Define freight use cases and perform market / stakeholder analysis for at least 3 cases (INL)	3/31/2019	Complete
Create infrastructure scenario description for at least 2 use cases based on real-world data and create model to simulate change points (INL, NREL, ORNL)	6/30/2019	Complete
Report on charging infrastructure strategies to support class 7-8 truck and first/last-mile delivery vehicle electrification (INL, NREL, ORNL)	12/31/2019	Complete

SEGMENTATION OF MOTOR CARRIER INDUSTRY

Electrification options heavily impacted by operation methods

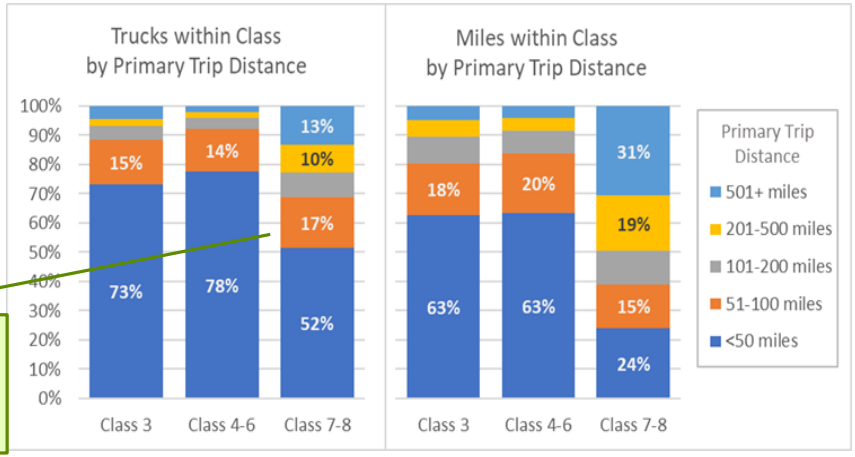
Cargo Ownership	Cargo Type	Operating Range	Shipment Size
For-hire Private	Freight Parcel Specialized	Local Regional Long-haul	Truckload Less-than-truckload

Number of vehicles	<5	5–25	26–100	101–250	251–1000	>1000
Percentage of fleets	95%	3.90%	0.6%	0.1%	0.04%	0.01%
Percentage of trucks	44%	14.4%	10.0%	%	7%	20%

Most fleets are less than 5 vehicles but still less than half total trucks

A very few large fleets account for 20% of trucks

Most trucks have a primary trip under 200 miles



DEPLOYMENT SOLUTION OPTIONS

Potential Charging Infrastructure Locations

Case Study 1

	Private Infrastructure			Public Infrastructure	
	Home (Independent owner/operator)	Depot	Delivery Location	Urban Route, Fast Charge (FC)	Truck Stop
Regional, Private	○	●	● Depending on ownership	●	● Extreme FC opportunity only
Regional, Less-Than-Truckload	●	●	● Depending on ownership	●	● Extreme FC opportunity only
Regional/Local Parcel Delivery	○	●	○	●	●
Long Haul, Private	○	●	○ Same as depot	○	●
Long Haul, Less-Than-Truckload	●	●	●	○	●
Long Haul, Truckload	●	● Larger fleets with home base	●	○	●

Case Study 2

Case Study 3

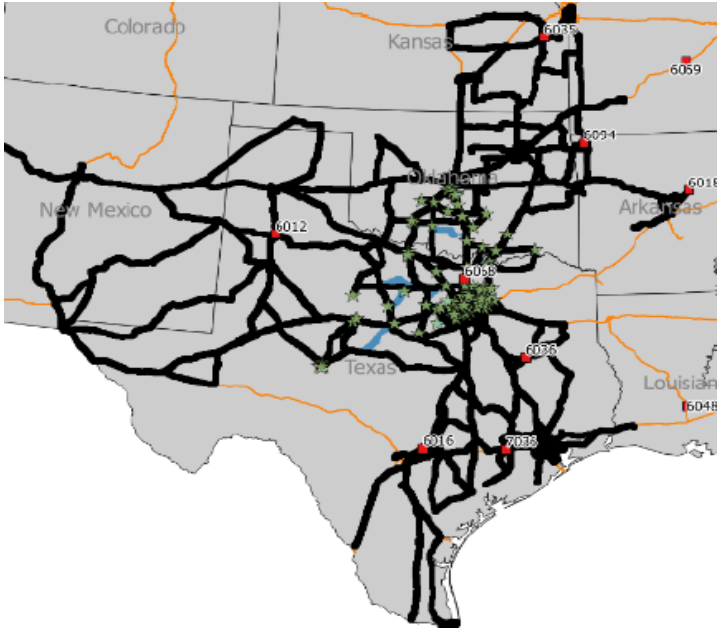
- ● - very likely / most preferred
- ● - less likely / less preferred; occasional use
- ● - not likely
- ○ - not applicable

TECHNICAL ACCOMPLISHMENTS AND RESULTS

CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

Examining real-world operations data

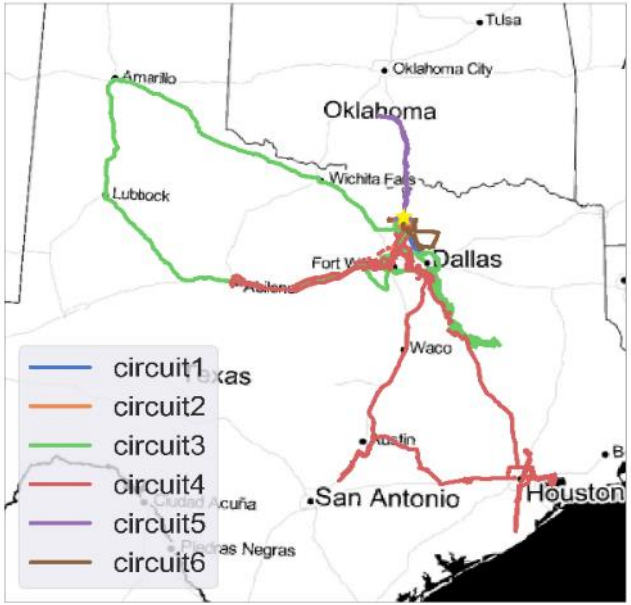
- Based in Dallas, Texas area
- Data loggers on 22 trucks
- Data collected over 1 month
- Class 7-8 trucks
- Private delivery locations



CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

Single vehicle used in varied ways

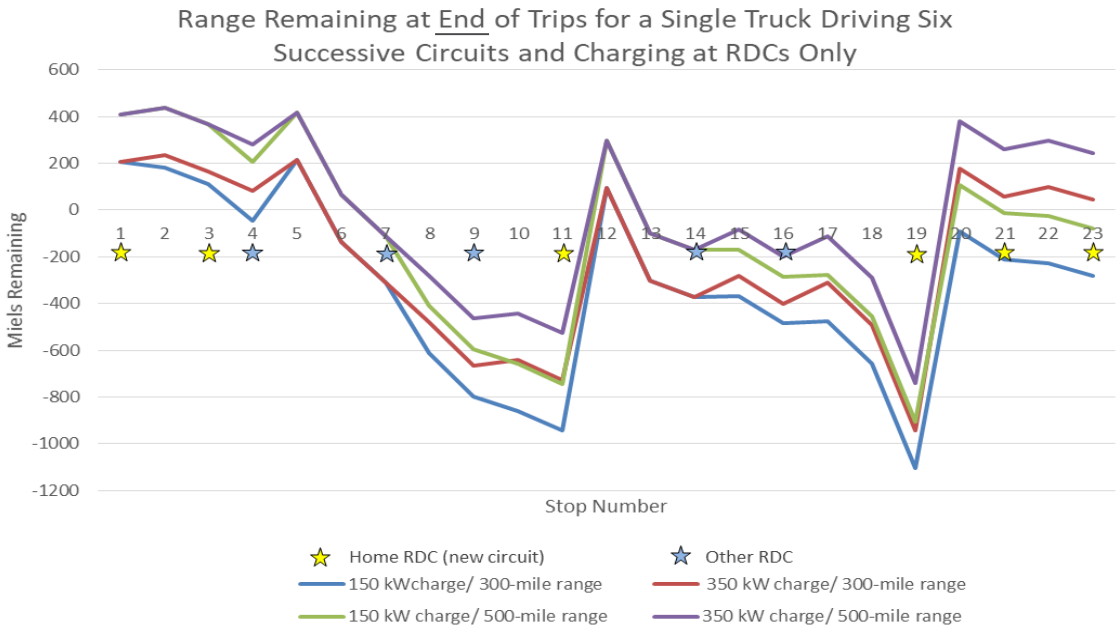
- A trip is travel between delivery locations or regional distribution centers (RDC)
- A circuit is the group of trips starting from and returning to the home RDC



Summary of Single Truck Case Study	
Total distance driven (miles)	3,733
Number of trips	24
Total dwell time (hours)	142
Number of trips exceeding 300-mile range	4
Number of trips exceeding 500-mile range	0
Circuits (trip chains starting and ending at home RDC)	6
Number of stops at home and other RDCs	11

CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

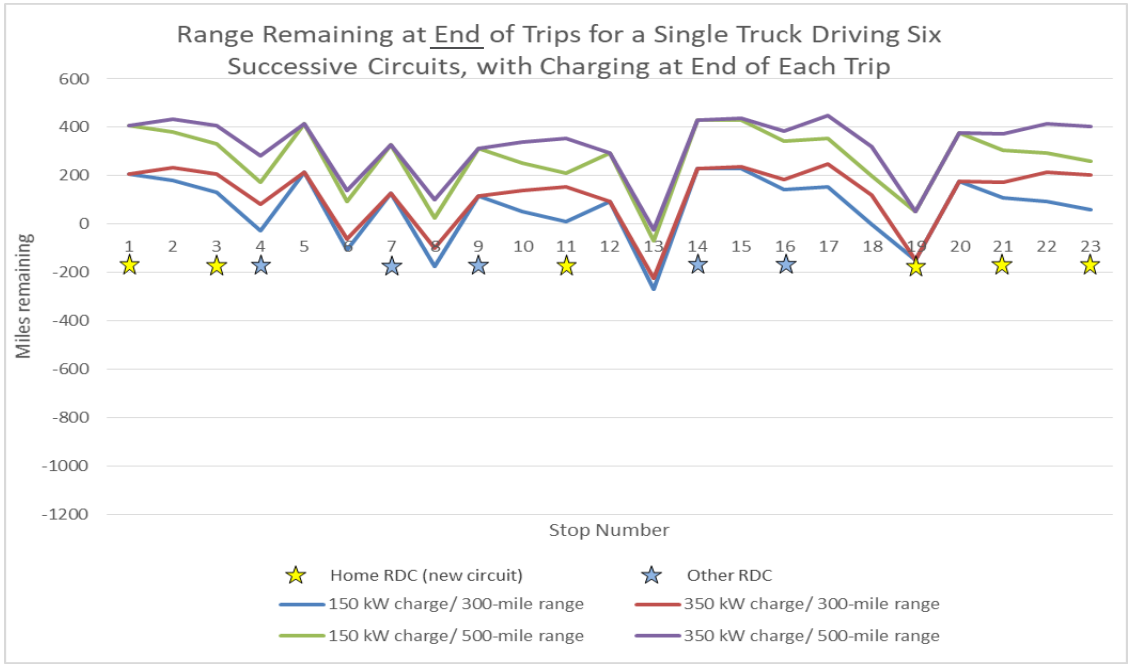
Depot-only charging not sufficient



- Range remaining is a result of charging at an RDC minus the miles to complete the trip
- Charging is for the entire time stopped at an RDC (stars)
- Negative ranges would have required public charging during trip

CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

Charging at delivery locations would enable many more trips



- Charging at every stop (delivery location and RDC) during entire time of the stop
- Most trips completed without deficit when charging at each location
- Some adjustment to operations would be required

CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

Charging at delivery locations enable significantly more routes

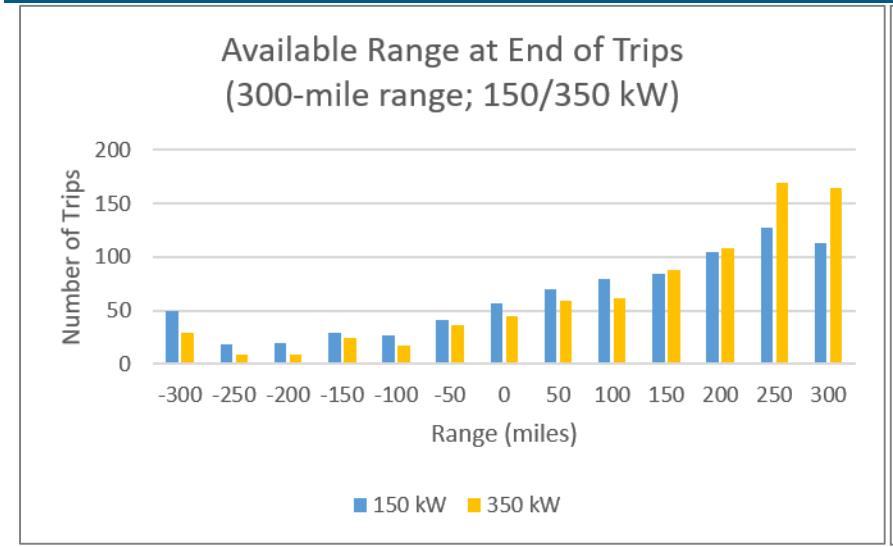
- RDC-only charging would require significant changes to operations
- Charging at each stop makes electrification plausible but is expensive
- Speed of charger is less significant when charging is available at all stops
- Electrification at these battery and charger levels may require significant operations changes

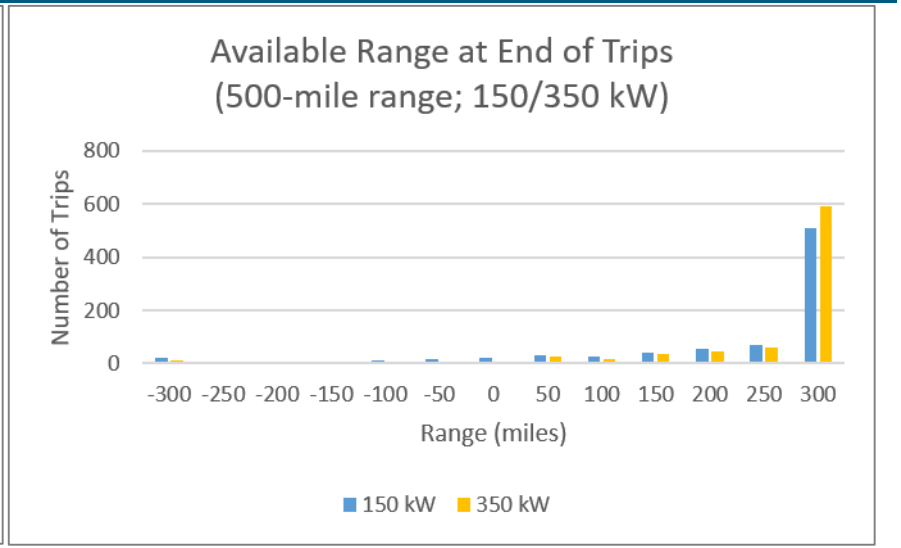
Vehicle Range (mi)	Charging Power (kW)	Charging Location	Percent of Trips Not Completed with Range Remaining
300	150	RDC only	77%
300	350	RDC only	67%
500	150	RDC only	63%
500	350	RDC only	51%
300	150	At all stops	30%
300	350	At all stops	21%
500	150	At all stops	11%
500	350	At all stops	6%

CASE STUDY 1: REGIONAL-HAUL PRIVATE MOTOR CARRIER

Longer range vehicles enable more operations

- 300-mile range may require more shifts in operations than 500-mile – even with charging at every delivery location
- Some trips not met by any private charging solution

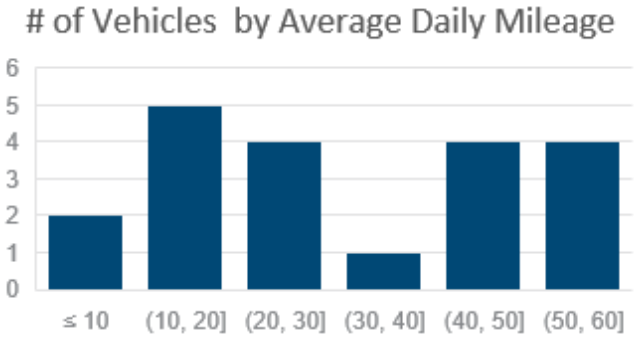




CASE STUDY 2: LOCAL PARCEL DELIVERY FROM DEPOT

Delivery locations enable significantly more routes

- Based in Columbus, OH
- Data loggers on 20 trucks
- 30 trucks in fleet
- Data collected over 1 month
- Class 6 trucks
- Centralized depot
- ~10 hour window when vehicles are available to charge



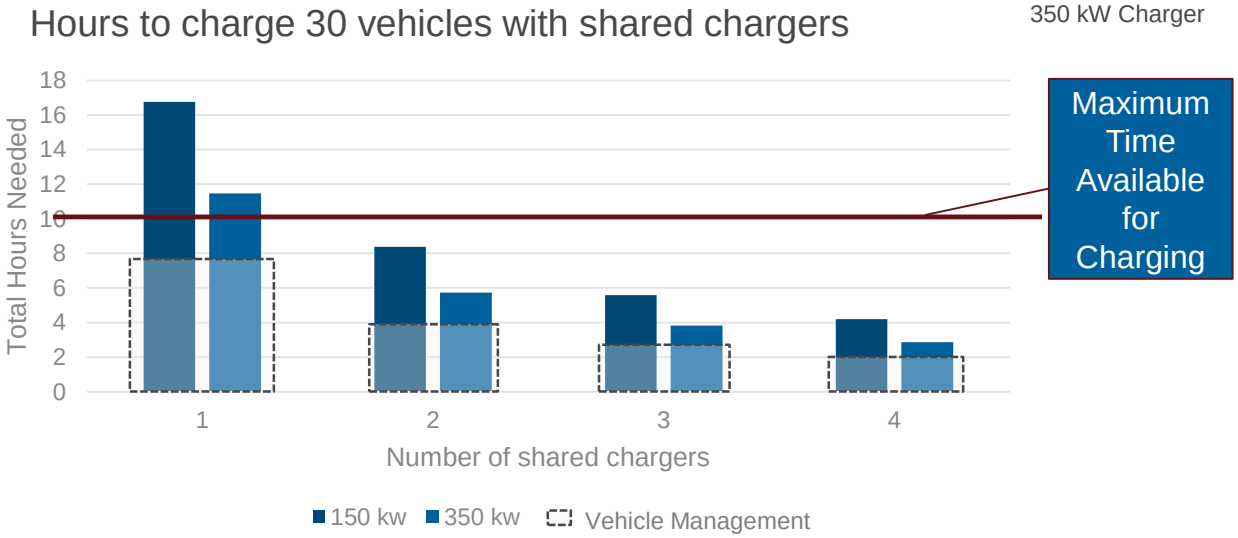
Fleet Daily Miles and Energy			
	Average per Truck	Total of 20 Trucks with Data Loggers	Total of all 30 Trucks in Fleet (Estimated)
Daily Distance	33.1 miles	662 miles	993 miles
Estimated Daily Electricity Consumption (assuming 1.4 kWh/mile)	46 kWh	927 kWh	1390 kWh

CASE STUDY 2: LOCAL PARCEL DELIVERY FROM DEPOT

Shared chargers would require time for vehicle movement

- Using shared chargers at depot requires movement of vehicles but can meet business case
- Time for moving vehicles has large impact, but it can be streamlined and the total charger idle time can be divided by multiple chargers
- Labor for management of charging increases cost

350 kW Charger

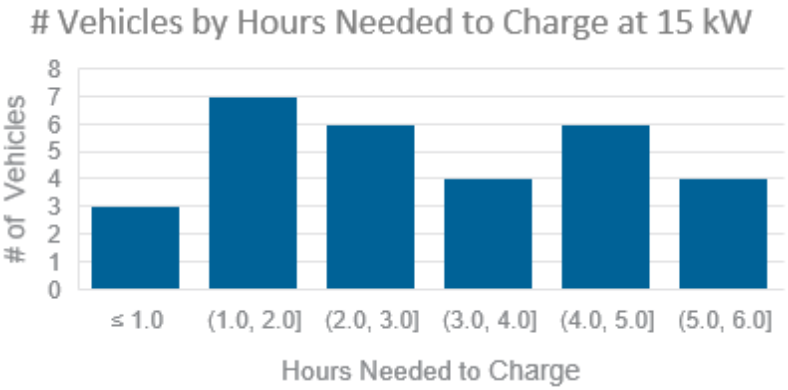


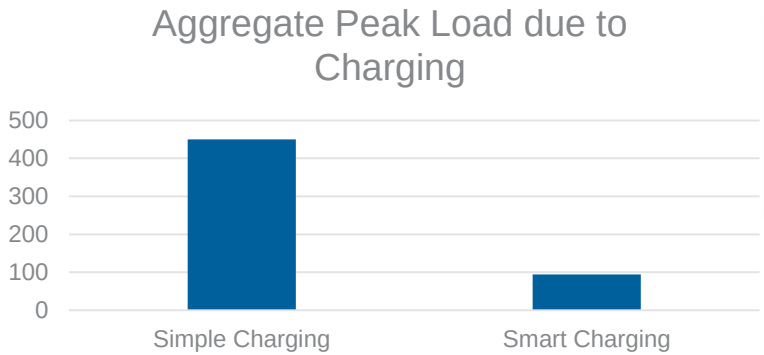
15 minutes allocated per vehicle for vehicle movement and management

CASE STUDY 2: LOCAL PARCEL DELIVERY FROM DEPOT

Low-power chargers dedicated to each truck would meet depot needs

- Level-2 Chargers (15 kW) at every truck station would meet needs
- Chargers much less expensive
- Peak energy needs can be reduced significantly by smart charging
- Reduces labor costs



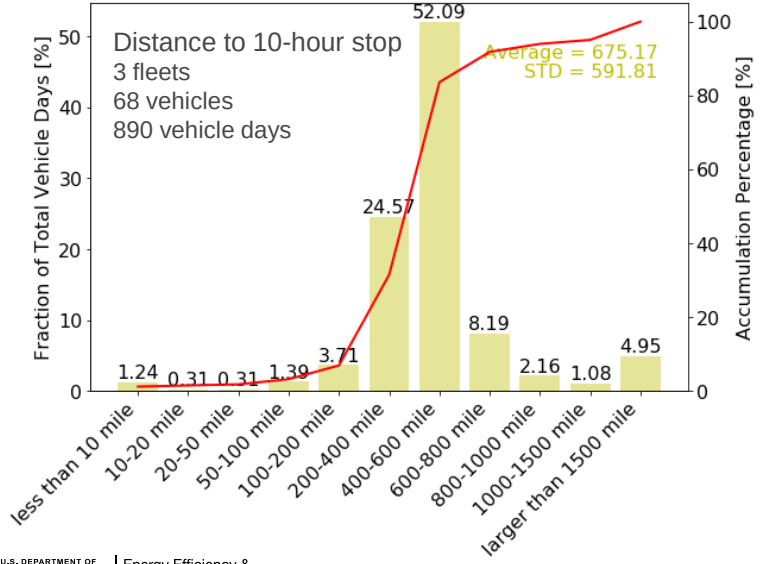


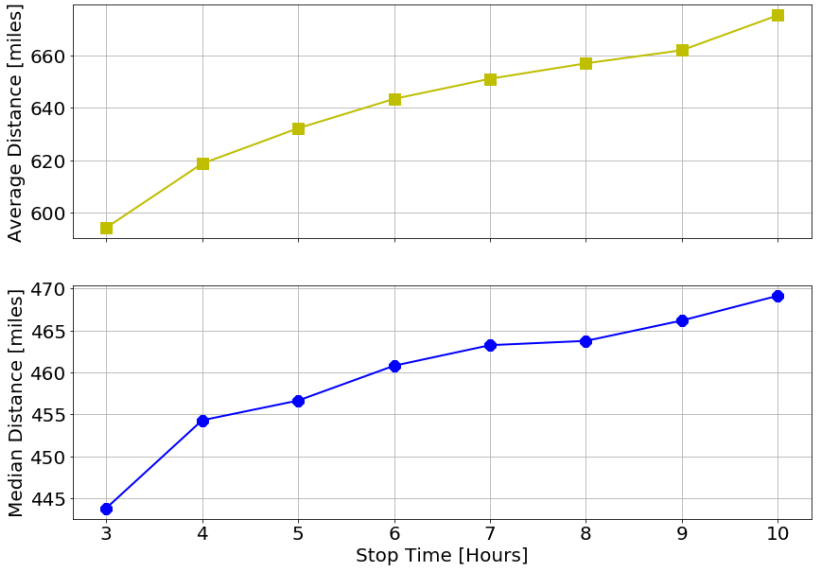
Level-2 Charger

CASE STUDY 3: LONG-HAUL TRUCKING

Public charging likely needed during drive cycle

- Typical shifts for long-haul longer than 500-mile range and would require charging during stops
- Median much smaller than average (due to high mileage weighting in few trucks)

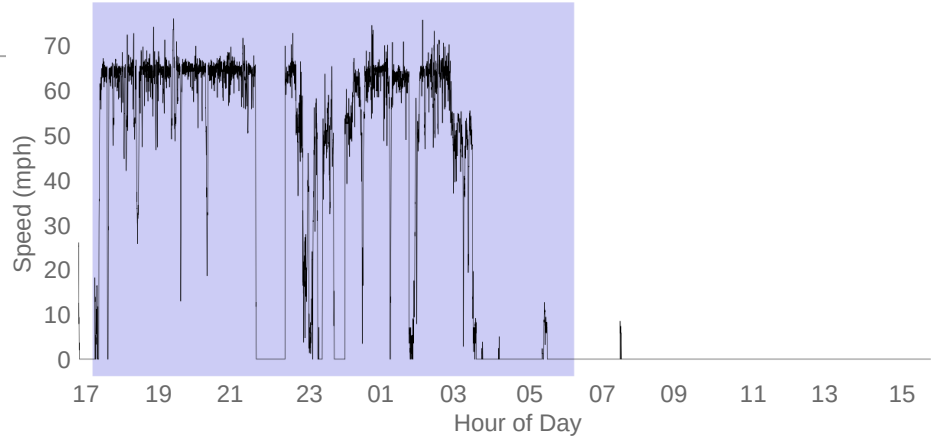


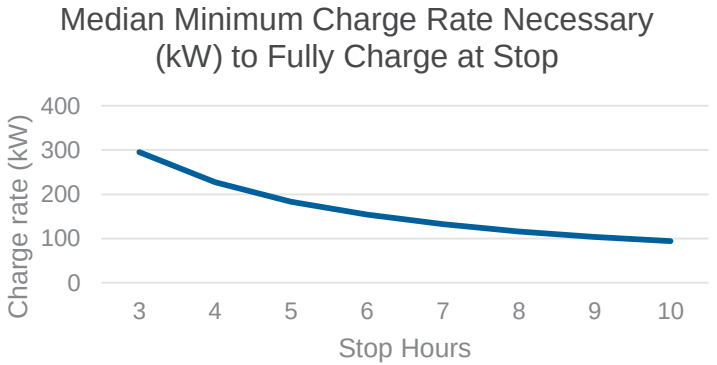


CASE STUDY 3: LONG-HAUL TRUCKING

Charging during typical breaks may meet needs

- Typical cycle allows for stops during day
- Representative 30 minute break would require 480 kW+ charge rate to complete route
- Needed charge rate is reduced as stop hours is increased





SYSTEMS APPROACH NEEDED

Charging must be integrated with entire operations

- Infrastructure investments need to be balanced with operations changes
- Fleets need tools to enable decisions
- This will allow solutions less expensive than ubiquitous charging

Purchase / Install Costs
External Storage
Land Use Needs
Facility Impacts
Grid Impacts / Availability
Technology Availability
Charging Labor Needed

Electricity Rates
Private peak rate impacts
Public rate premiums
Labor for charging management
Depreciation / Maintenance

Vehicle Purchase Costs
Battery Range
Weight restrictions
Technology approach (wired / wireless, etc)
Fuel Savings
Maintenance Savings
Incentives / Motivations

Charge time on route
Driver time constraints
Impacts to route time
Impacts to routing
Public infrastructure availability

RESPONSE TO REVIEWERS

Reviewers felt the topic was applicable and significant. They also said that the scope and accomplishments seemed appropriate for the size and time of the project.

- The research was completed and reported as planned

Reviewers pointed out that size of fleet would be significant for access to investment.

- This is a valuable insight and we have added this to our list of considerations.

Reviewers suggested future work look for additional collaborations and work to assist industry.

- We have tried to incorporate this suggestion into our future research suggestions.

COLLABORATION

Industry and Lab Partners

National Laboratories:

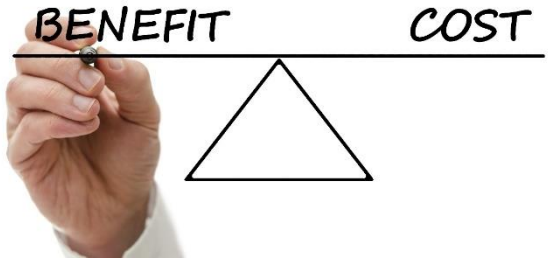
Industry Involvement:

- Interviews with national fleet operators and parcel delivery companies
- Discussions with American Trucking Institute
- Input from national trucking consortium
- Industry statistics and research input
- Data logging from real-world operations and stored in FleetDNA

POTENTIAL FUTURE RESEARCH

Help industry to find solution value

- Work with industry, technology, and service providers to identify demands and solutions
- Develop tools to balance infrastructure costs to operations changes
- Look for ways to reduce costs and take advantage of slow-charging
- Help businesses minimize grid / cost impact
- New tools to enable systems-level approach



Any proposed future work is subject to change based on funding levels.

SUMMARY

Systems-Level Approach Enables Electrification

- Industry operations impact electrification
- Operations models enable charging methods
- Balance of costs and operations needed for most effective solutions
- Ubiquitous charging not most economical solution
- Take advantage of natural charge times built into daily cycle

Potential enablers:

- **Medium-power charging at delivery locations**
- **Low-power charging at depots**
- **High-speed charging at truck stops during breaks**
- **Operations Modifications**

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MOBILITY FOR OPPORTUNITY

FOR MORE INFORMATION
Victor Walker
Victor.Walker@inl.gov
Idaho National Laboratory

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